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PROPERTIES OF *CELTIS ZENKERI* ENGEL: A LESSER-KNOWN TIMBER SPECIES FROM KILINDI DISTRICT, TANZANIA

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ABSTRACT

This study was conducted to provide some of the basic physical and strength properties of wood of *Celtis zenkeri* Engel. which is among the lesser-known and lesser-utilized timber species from Tanzania. *Celtis zenkeri* belonging to the family Ulmaceae is currently being harvested for wood fuel and building poles thus being under-valued and placed in class V timbers since the basic properties of its wood are not yet known. The objective of this study was therefore, to determine and assess some of the basic physical and mechanical properties of *C. zenkeri* specifically colour, texture, basic density, Static bending (Modulus of Flasticity, Modulus of Rupture, Work to maximum Load and Total work), Compression parallel to grain, Shear and Cleavage stress. Relationships between basic density and the mechanical properties were also assessed. Data for this study were collected from three mature and defect free sample trees objectively selected from Kilindi district in Tanga region. Each sample tree produced three logs; from bottom, middle and upper part of the bole. Test specimens were extracted from the samples and by using standard methods, the physical and mechanical properties were determined. The following are the wood strength properties obtained for *C. zenkeri*. Basic density (655 kg m^{-3}) and Total Work (21,916 N mm^{-2}), Modules of rapture (198 N mm^{-2}), Work to maximum load (0.360 N mm^{-3}) and Total Work (0.598 N mm^{-2}). Others are; Cleavage strength (24.56 N mm-width), compression strength (97.1 N mm^{-2}) and Shear strength (28.7 N mm^{-1}) *Celtis zenkeri* wood was found to have desirable values to be used for hand tools, joinery, building, plywood, artificial limbs and flooring furniture.

Key words: Basic density - Tanga, *Khaya anthotheca, Eucalyptus paniculata, Fagaropsis angolensis*

INTRODUCTION

Tanzania has valuable natural assets in its forests in terms of timber trees, but only a few of the well known trees are utilized and often used for purposes for which other equally suitable but cheaper tree species could be used (Bryce, 2000). These other timbers that are merely market acceptable are termed as lesser-known timber species. It would be simple to define lesser-known timber species as commercially less accepted species left in the forest after logging operations. Hansom (1983) defined lesser-known timber species as those species that are not being put to best advantage, although many commercial species are not being put to best advantage either.

Celtis zenkeri Engel. (Mgomoka), belonging to the family of Ulmaceae is among many lesser-known and therefore, lesser utilized timber species in Tanzania. According to Bryce (2000), the species is found in lowland rain forest, altitude ranging from 250 – 1200 m above sea level in Tanzania, Uganda, Sudan, Democratic Republic of Congo, Angola and West Africa. In Tanzania CELP (2001) noted that *C. zenkeri* is common in Tanga, Morogoro and Arusha regions.

There has been considerable discussion about the fuller utilization of tropical forests with particular reference to the lesser-known species, but the problem has remained intractable and little can apparently be done (Freezaillaih, 1990). Eddowes (1980) in discussing the technical aspects of promoting the lesser known timber species in Papua New Guinea identified the following problems; difficulty in identification of timber species, inadequate data on physical and mechanical properties, incorrect market into wrong end uses, irregular or inadequate supplies and poor grading. These problems however apply to lesser known species not only in Papua New Guinea but in all closed tropical forests.

The main objective of this study was to determine and assess some of the basic physical and strength properties of wood of *Celtis zenkeri*. Specifically, the study was conducted to determine the physical properties of *C. zenkeri* (tree dimension, form and quality, wood appearance, wood basic density) and mechanical properties of *C. zenkeri* (static bending properties including modulus of elasticity (MOE), modulus of rupture (MOR), work to maximum load, compression parallel to grain and tangential shearing)

MATERIALS AND METHODS

Study area description

The study samples were collected from a forest in general land bordering Kilindi Catchment Forest Reserve in Tanga Region. This forest is situated about 25 km from Kwediboma and 66 km from Handeni towns, between latitudes 5°33' - 5°40'S and 37° 33' – 37° 36'E. According to Lovert and Pòcs (1993) the area is elevated at 760 – 1,520 metres above sea level, receiving annual rainfall ranging from 1,500 – 2,000 mm on the eastern side and 1,000 – 1,200 mm on the western side. Whereas the mean maximum temperature is 24°C in February, the mean minimum temperature is 19 °C in July.

The forests cover range from riverline to lowland forests and are of the Eastern Arc type which is rich in species of restricted distribution (CELP, 2001). Species found in association with *C. zenkeri* were *Newtonia buchnanii, Allanblankia stuhlmanii, Albizia versicolor, Antiaris toxicaria, Nesogordonia holtzii, Sterculia appendiculata* and *Pterocarpus* spp. These forests have black sandy loam soils, rich in humus formed on gneissic basement rock.

Sampling procedures

Samples of *Celtis zenkeri* were objectively selected from three mature and defect free trees after thorough observation of their physical appearance. These represented small, medium and large diameter classes. The trees were felled and their diameters at breast height and total height recorded. Three billets, each measuring 1.5 m length were cut from breast height upwards, marked and sawn to central cants 65 mm thick. The cants were transported to the Wood Utilization Laboratory of Sokoine University of Agriculture for further processing. The cants were re-sawn into 30 mm x 65 mm x 1,500 mm planks from the pith left and right towards the bark. These planks were then numbered and labeled sequentially to show the position of extraction and direction of sawing and stacked for drying until the moisture content was below 15 %. The planks were further re-sawn and planed down to 20 mm x 20 mm 1,500 mm sticks/scantlings. It is from these sticks, where the small clear specimens for testing various properties were extracted.

Data collection

Physical properties

Moisture content

The moisture content was carried out in accordance to ISO 3130 (1975). The strength values of test specimen with moisture content lower or more than 12 % were adjusted according to Desch (1981).

Colour and texture

The colour of the timber of *Celtis zenkeri* was determined using standard methods described by authentic samples after seasoning and planning the specimens. The texture was determined visually and supplemented by feeling with hand the fineness of the planed timber surface.

Basic density

For determination of basic density, 50 mm wood test samples were extracted from scantlings before drying. The basic density was determined according to the method described in ISO 3131 (1975).

Mechanical properties

The scantlings were further reduced to 30 mm x 30 mm x 1,500 mm, dried down to moisture content below 15% then planed to 20 mm x 20 mm x 1,500 mm sticks. From these sticks, different test samples of various dimensions were extracted (Table 1). The were carried out following the procedures described by BS 373 (1957; 1976), Lavers (1969), Panshin and de Zeeuw (1970), ISO 3133 (1975) for testing clear wood specimens.

Table 1: Test sample dimensions and count used for strength properties determination for *Celtis zenkeri* from Kilindi district Tanga Tanzania

Type of Test	Sample dimensions (mm)	Sample count
Static bending	20 x 20 x 300	68
Shear parallel to the grain	20 x 20 x 20	68
Cleavage	20 x 20 x 45	68
Compression parallel to grain	20 x20 x 60	68

RESULTS AND DISCUSSION

Physical properties

Tree dimension, form and quality

Celtis zenkeri is a much branched tree, growing up to 30 m tall and is characteristically buttressed at the base up to 3 m high (Polhill, 1966).The bole is straight, slender and has diameter at breast height (Dbh) reaching 90 cm. Records for some of the better-utilized timber species in Tanzania indicate that *Pterocarpus angolensis, Afzelia quanzensis* and *Dalbergia melanoxylon* rarely have suitable bole for timber exceeding 10 m and are usually small to medium sized in diameter (Chudnoff, 1984; Burgess and Clarke, 2000; Ball, 2004).

Colour and texture

The wood of *Celtis zenkeri* is whitish in colour with no distinction between heartwood and sapwood. There is much resemblance in colour with of such softwoods as *Pinus* spp. and *Podocarpus* spp.which has a light yellow to yellowish brown colour, as documented by Bryce (2000). Other species with similar timber colours include *Schinziophyton rautanenii* (WAC, 1990), *Fraxinus americana* and *Fagus sylvatica* (Knoke, 2003). If wood colour is a pre-requisite, *Celtis zenkeri* can be used in place of these timber species. Further observations on the timber of *Celtis zenkeri* revealed that the species has fine textured wood which also, attains good finish in planing.

Basic density

Celtis zenkeri has average basic density of 656 kgm^{-3} which is the same as that reported by Lavers (1969) of *Khaya anthotheca* and *Pterocarpus angolensis* (657 kgm^{-3}) and higher than that of *Milicia excelsa* (620 kgm^{3}). Panshin and De Zeew (1970) classified all woods with density above 500 kgm^{-3} as heavy. *Celtis zenkeri* can therefore be considered in the same group as high density timber species.

Within a tree, the basic density of *Celtis zenkeri* showed variations in both radial and axial directions as shown in Figure 1 and 2 respectively. In the radial direction, the density increased from pith to bark. In the axial direction however, the density was lowest at the base, increasing to a peak at the middle and falling again to the top.

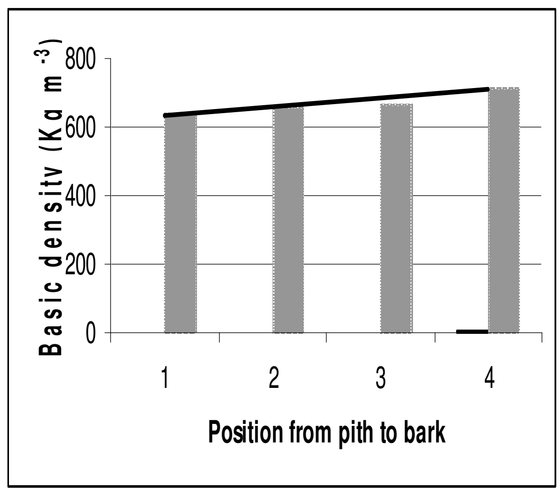

Figure 1: Radial basic density variation

Strength properties

Static bending

Modulus of elasticity

The Modulus of elasticity (MOE) of *Celtis zenkeri* was found to be 21,916 Nmm^{-2}. This value is close to that of *Eucalyptus paniculata* of 24,879 Nmm^{-2} reported by Lavers (1969). Other documented values by the same author include those for *Fagaropsis angolensis* (13,565 Nmm^{-2}), *Milicia excelsa* (11,270 Nmm^{-2}), *Khaya anthotheca* (9,604 Nmm^{-2}) and *Pterocarpus angolensis* (8,443 Nmm^{-2}).

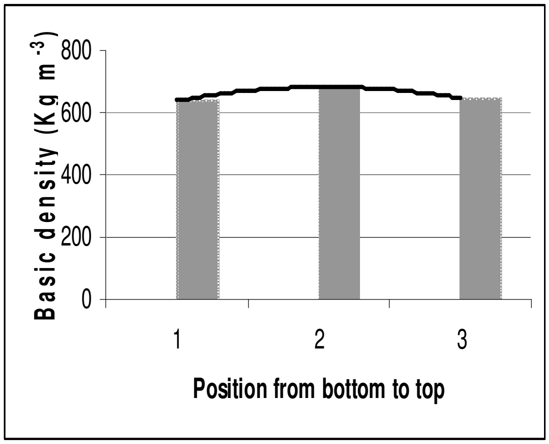

Figure 2: Axial basic density variation

The variation of MOE within a tree in radial direction of *Celtis zenkeri* is shown in figure 3. The wood of *Celtis zenkeri* shows slight differences in MOE in radial direction. In axial direction, the MOE at the bottom is about 23,000 Nmm^{-2}, increasing at the middle to a peak of 23,800 Nmm^{-2} and then falls at the top to 20,900 Nmm^{-2} (Figure 4).

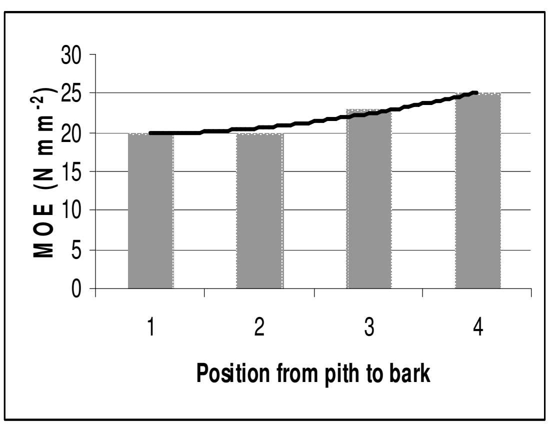

Figure 3. Radial MOE variation of *Celtis zenkeri*

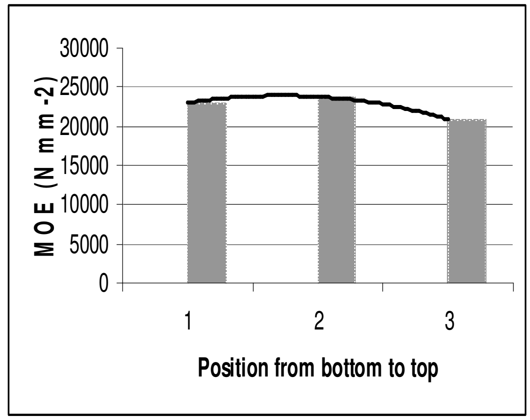

Figure 4. Axial MOE variation of Celtis zenkeri

Modulus of rupture

The Modulus of rapture (MOR) of *Celtis zenkeri* was found to be 198 Nmm^{-2}. This is greater by 61.6% than that of *Khaya anthotheca* of 76 Nmm^{-2}, reported by Lavers (1969). There were also slight within tree variations in Modulus of rupture strength. In the radial direction the strength was 170 Nmm^{-2} at the pith, decreasing outward then increasing to the maximum of 220 Nmm^{-2} close to the bark (Figure 5). In the axial direction, the trend shows a slight increase from the butt to the middle from 198 to 212 Nmm^{-2} and then a decrease to 185 Nmm^{-2} at the top (Figure 6).

Work to maximum load

It was observed that, the work to maximum load of *Celtis zenkeri* is 0.360 mmNmm^{-3} which is greater than those reported by Lavers (1969) of *Pterocarpus angolensis* (0.093 mmNmm^{-3}), *Fagaropsis angolensis* (0.114 mmNmm^{-3}) and *Khaya anthotheca* (0.07 mmNmm^{-3}).

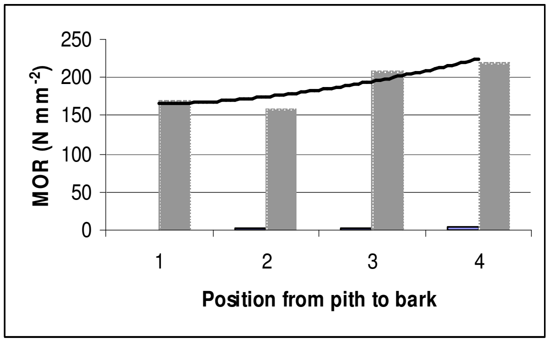

Figure 5 Radial MOR variation of *Celtis zenkeri*

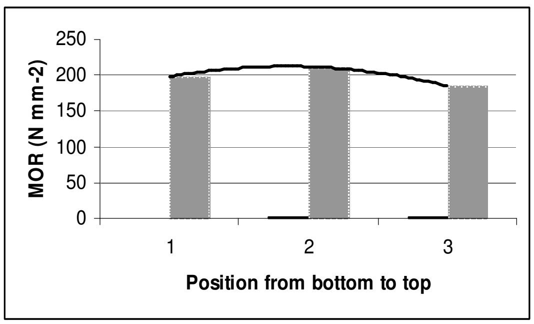

Figure 6: Axial MOR variation of *Celtis zenkeri*

The variations in the work to maximum load in both radial and axial directions assumed similar trends with variations in basic density in the two directions. Several authors including Panshin and De Zeew (1970), Desch (1973;1981), and John and Jim (1982) have pinpointed the importance of the density of wood as the best indicator of its strength.

Work to total fracture

Compression parallel to the grain

The mean value of compression strength parallel to the grain for *Celtis zenkeri* timber was 97.120 Nmm^{-2}. This value is greater than that of *Fagaropsis angolensis* (61.7 Nmm^{-2}) and *Khaya anthotheca* (48.3 Nmm^{-2}) documented by Lavers (1969). The wood of *Celtis zenkeri* shows that there is an increase in the mentioned strength feature from pith (90 Nmm^{-2}) to the bark (110 Nmm^{-2}). In the axial direction, there is high compression parallel to the grain at the bottom (102 Nmm^{-2}) decreasing to 100 Nmm^{-2}) in the second log and reaching a minimum of 91 Nmm^{-2}) at the top.

Shear strength

The shear strength of *Celtis zenkeri* wood was 28.69 Nmm^{-2} which is higher than that of *Eucalyptus paniculata* (20.2 Nmm^{-2}) and *Fagaropsis angolensis* (19.6 Nmm^{-2}). *Celtis zenkeri* therefore shows superiority for use in designing of joints.

Whereas in the radial direction shear strength increased from pith (88 Nmm^{-2}) to the bark (110 Nmm^{-2}), in the axial direction shear strength decreased from 29 Nmm^{-2} in the butt to (27.75 Nmm^{-2}) in the middle and then increased to 29.75 Nmm^{-2} towards the top of the tree.

Cleavage strength

Celtis zenkeri was found to have cleavage value of 24 Nmm^{-2}-width. The species is much stronger in this aspect than *Eucalyptus paniculata* (6.5 Nmm^{-2}-width), *Pterocarpus angolensis* (12.7 Nmm^{-2}-width), *Khaya anthotheca* (11 Nmm^{-2}-width) and *Fagara angolensis* (15.8 Nmm^{-2}-width), as documented by Lavers (1969). The wood of *Celtis zenkeri* shows to some extent variation within tree in radial direction being increasing steadily from pith (22.5 to about 27.0 Nmm^{-2}-width) and then a sudden decrease close to the bark (25 Nmm^{-2}-width). The trend of axial variation showed the cleavage strength being high in the butt and middle logs (24.75 Nmm^{-2}-width) and fall to 24.3 Nmm^{-2}-width in the top log.

Relationship between basic density and strength properties

From the results of this work, basic density influences other wood properties as shown in Table 2a and 3b for radial and axial directions, respectively.Table 2a: The influence of basic density on strength properties of *Celtis zenkeri* in the radial direction

Parameter	**Regression equation**	**R^2**	**p-value**
Modulus of elasticity	$Y = -20184 + 62.43\chi$	0.72	<0.01*
Work to maximum load	$Y = -0.322 + 0.001\chi$	0.90	<0.01*
Modulus of Rapture	$Y = -228.45 + 0.63\chi$	0.82	<0.01*
Total work	$Y = -0.787 + 0.0021\chi$	0.54	<0.01*
Cleavage strength	$Y = -6.875 + 0.025\chi$	0.23	0.04**
Compression strength	$Y = -61.154 + 0.234\chi$	0.94	0.67
Shear strength	$Y = 3.195 + 0.038\chi$	0.16	0.03**

Table 2b The influence of basic density on strength properties of *Celtis zenkeri* in the axial direction

Parameter	Regression equation	R^2	Grade of correlation
Modulus of Elasticity	$Y = -216.21 + 34.0\chi$	0.29	<0.01*
Modulus of rupture	$Y = -86.70 + 0.434\chi$	0.62	<0.01*
Work to maximum load	$Y = -0.062 + 0.0006\chi$	0.44	<0.01*
Total work	$Y = -1.2812 + 0.0029\chi$	0.52	<0.01*
Cleavage strength	$Y = 20.974 + 0.055\chi$	0.10	0.03**
Compression strength	$Y = 65.6158 + 0.048\chi$	0.04	<0.74
Shear strength	$Y = 49.192 + 0.0312\chi$	0.87	0.05**

* Statistically significant at $p \leq 0.01$, ** Statistically significant at $p \leq 0.05$

Table 3 Basic density and some strength properties of *Celtis zenkeri* and some of the better-known species in Tanzania

Species	*Celtis zenkeri*	*Eucalyptus Paniculata*	*Fagaropsis angolensis*	*Khaya anthotheca*
Basic density (Kgm^{-3})	656	626	673	657
MOE (Nmm^{-2})	21916	24879	13565	9604
MOR (Nmm^{-2})	198	182	110	76
Wmax ($mmNmm^{-2}$)	0.360	-	0.114	0.07
Wtotal ($mmNmm^{-2}$)	0.598	-	0.148	0.109
Shear (Nmm^{-2})	28.7	20.2	19.6	10.1
Compression (Nmm^{-2})	97.1	96.3	61.7	48.3
Cleavage (N/mm-width)	24	6.5	15.8	11

Source: Lavers (1969)

Summary

The studied properties of *Celtis zenkeri* tree indicate suitability of this species for commercial timber extraction. The tree has good dimensions, form and quality with its wood having whitish colour which can easily be artificially stained to any desirable colour. Most of the other physical properties and strengths are comparable with those of the better known and utilized timber species. Table 3 shows some of the tested strength properties of *Celtis zenkeri* compared with those of the better-known species of *Fagaropsis angolensis*, *Eucalyptus paniculata* and *Khaya anthotheca*

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The timber of *Celtis zenkeri* is whitish and in this aspect, it can be used as a substitute of such species as *Pinus* spp, *Podocarpus* spp., *Schinziophyton rautanenii, Fraxinus americana* and *Fagus sylvatica.*

The timber is heavy and the strength properties of *Celtis zenkeri* make the species suitable in applications where compression, toughness and shock resistance is required, for instance in floorings, handles and sports gears. The timber is also suitable for uses where nails, screws and other fasteners are employed such as in designing of joists and package cases.

Within a tree of *Celtis zenkeri*, the most dense wood is around the pith in the middle section of the tree and lightest is near the bark near the butt end of the first log, in the buttress region.

Recommendations

Since *Celtis zenkeri* has high strength values, it should be promoted for structural timber uses rather than losing it through inferior uses. In the strength aspects therefore, *Celtis zenkeri* timber can substitute *Khaya anthotheca, Pterocarpus angolensis, Eucalyptus paniculata* and *Fagaropsis angolensis*. When colour is of great importance, the species can not substitute unless *Celtis zenkeri* is varnished.

The middle section of the tree bole should be considered and the wood near the butt end avoided, in applications where strength is of at-most importance.

More research on other properties of *Celtis zenkeri* such as anatomical, chemical and natural durability are needed in order to gain knowledge of its full utilization potentials.

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